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ABSTRACT

The stimulus properties of the letters b, d, p, and q were investigated in an attempt to demonstrate that the common reversal of these letters by beginning readers is in part determined by the vertical aspect of the stimulus figure. One hundred eighty kindergarteners were randomly selected from a racially mixed population and randomly assigned to one of four visual matching of letters tasks. All tasks presented letters of uniform size, shape, density, and presentation except for certain variations relevant to each of the four experimental treatments. All four treatments required subjects to match lower case letters to one lower case stimulus letter printed in the center of the page two inches from the top. Subjects were instructed to draw a cross on each letter on the rest of the page that was exactly the same as the stimulus letter at the top. The letters presented on the rest of the page were designated response letters. The response letters included those identical to the stimulus letter and three foils. The results indicated that the vertical properties of b, d, p, and q influence the letter reversal behavior of kindergarteners. In addition, reducing the dominance of the vertical aspects of these letters resulted in marked reduction of reversal errors. (WR)

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THE EFFECT OF VERTICALITY AS A STIMULUS PROPERTY ON THE LETTER DISCRIMINATION OF YOUNG CHILDREN

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INTRODUCTION

Traditionally, research of children's letter reversals has focused on developmental and "directionality" factors to explain b d p q confusions. In contrast, this study investigated the stimulus properties of these letters. Specifically, this study demonstrated that kindergarteners' reversals of b d p q are, in large part, determined by their attraction to the vertical aspect of stimulus figures. While the tendency for the vertical aspect to dominate the young child's perception is, of course, a developmental phenomenon, the fact that the nature of the stimulus is the precipitator of reversal responses leads to very practical possibilities for reducing these letter reversals at the beginning reading stage.

In a much wider sense, this study derives from a definition of the behavioral researcher's domain as the manifest features of stimuli, response and feedback conditions in contrast to the more traditional definition of psychology as the study of such constructs as "perception" (specifically "directionality" or "laterality"). Such a difference in definition does not refute theories of perception--in fact, this study supports such theories. But the restriction of the researcher's domain to behavior in relation to stimulus, response and feedback conditions leads to much stronger prediction and control factors in research design. In education, furthermore, it leads to more direct application to the solution of real-world school problems.

PREVIOUS RESEARCH

The research on letter reversals falls into two categories, endogenic studies and exogenic studies.

Endogenic Studies: By far the most popular approach to explaining letter reversals, the endogenic approach concentrates on properties of the reader. Vernon was one of the earliest proponents of this point of view. She felt that the percept depended upon the subjective qualities brought by the observer to the perceiving task. Those qualities, claimed Vernon (1937), were both innately and environmentally determined. Piaget's (1967) influence and Gesell's studies of visual development (1949) set the tone for decades of research that concentrated on properties of the subject rather than on properties of the stimulus. For example, Piaget's studies concentrated on the developing child, describing how visual processing proceeds from viewing objects by topological relations to Euchlidean and projective spatial relations (Piaget, 1967). These studies did not ignore interaction between the subject and the environment. In fact, many of these studies attempted to isolate the relative roles of heredity and environment in visual perception development. But their concentration was on the subject. Out of this background came studies by Bender (1938), Pratt (1950), Bell (1952), Rivoire (1961) and Foresman (1966). Essentially these studies established that different factors in the coding of visual information are age specific, but they are not independent of environmental stimulation.

The direct application of this point of view to reading instruction is seen in researchers' attempts to explain underachievement as defects in perceptual processes or even in the lack of "perceptual readiness."

As early as 1923, Fildes found that non-readers showed poor visual form differentiation when there was a change in spatial orientation. She regarded this aspect of visual discrimination as a specific visual perceptual skill (Fildes, 1923). Monroe (1932) studied stimulus properties of letter shapes

but emphasized letter recognition problems as endogenically derived from the subjects' abilities--more specifically from his inabilities. The visual perceptual factor of eidetic ability as isolated by Petty (1939) was found to be higher in children who became good readers. A review of studies from the 1940's led Betts to the conclusion that form perception was the basic prerequisite to reading (Betts, 1953). This was reaffirmed by Durrell and Murphy (1963).

In a classic study of the relationship of visual perception to reading, Goins hypothesized that select tests of visual perception reveal various types of perceptual abilities and relate to reading competence. She found the common factor in good readers to be the ability to keep in mind a configuration against distraction. She called this "strength of closure" (Goins, 1958).

In 1960, Feldman supported the specificity of visual perception of skills with age and experience and suggested that the lack of synchronization of visual perception and required reading skills might impede school achievement (Feldman, 1969).

Interest was now centered on preventing reading failures. De Hirsch studied tests designed to uncover potential reading problems. The ability to perceive and reproduce shapes and figures was found to be indicative of future reading failures (De Hirsch, 1966). These kinds of studies led to the theory that training of specific visual perceptual skills that were not adequately developed in the child would lead to future achievement in reading. Frostig developed a visual perception test as a predictor of school success and a program based on the skills assessed by the test (Frostig, 1964).

More current research has indicated that training of visual perception skills leads to the improvement of these skills but does not bring about increased reading achievement (Rosen, 1965, R. Cohen, 1966; McBeath, 1966; Foresman, 1966; Buekland, 1969; S.A. Cohen, 1969; Balow, 1971).

Thus, research offers us the explanation of the coding of visual information as a function of age with variation in environmental stimulation.

The relationship of visual perception to reading disabilities has been a constant subject of investigation. These studies are based on the premise that specific perceptual behaviors are involved in reading and that these behaviors effect reading achievement. Since learning to read and visual perception are developmental processes, the use of prediction of one variable to the other has been the emphasis of these investigations.

The Study of Reversals: Concurrent with the research previously described which focused on the relationship of visual perception to reading, there was also research pinpointing the specific problem in reading, referred to as "reversals."

Smith (1928) states that certain letters of the alphabet are not only quite similar in form to others, but are merely rotations and reversals of others like b, d, q, and p. These letters according to Smith produce the most confusion and difficulty.

The reversal phenomenon in reading has been studied primarily from the focus of directional orientation, again concentrating on properties of the subject rather than on properties of the environment. Vernon has divided this focus into two approaches. The first concentrated on the ability to discriminate between different orientations of identical figures. The second focus is on the ability to discriminate left and right in relation to one's body and other persons' (Vernon, 1957). Orton, a neurologist, pursued the latter point of view and felt that if dominance fails to be established in the child, reversals occur. He labeled this condition "strephosymbolia," or twisted symbols. He postulated that these reversals were "kinetic reversals" and occurred in retarded readers. He stressed the theory that reversals were caused by "confusion" in mental imagery (Orton, 1928; 1937).

Dearborn (1925), on the other hand, theorized that reading reversals are a problem of confusion or motor activity and felt that mixed dominance helped cause the confusion of letter reversals.

Ignoring the Orton thesis, Davidson studied the confusing letters, b, d, p, and q, and found that the up and down of a q and d were discriminated by more than 50% of the children of kindergarten age but that the left and right b and d were only discriminated by 10% of the same age children. Her study also showed that visual recognition of correct form increased with age (Davidson, 1935). The gradual disappearance of reversal errors as a correlate of age was further confirmed by Hildreth (1934) and Bennett (1938).

Potter (1949) approached the problem of perception by examining different orientations of identical objects. She pinpointed the ability to avoid mirror images as crucial for early reading success. Krise (1949) also found that reversal errors were a problem in visual space perception but did not relate them to body orientation. Herman (1959) stated that the reversals of b and d are "primitive errors" and are characteristic of congenital word blindness.

Kephart (1960) in his studies of the slow learner, adhered to a dysfunction in spatial orientation approach to account for reversal errors of b and d and rotation errors of p and d.

Harris and Roswell (1953) postulated that real directional confusion is a cue to reading reversals. In further studies, Harris found that a positive relationship existed between right and left discrimination both in reference to one's own body parts and others', and reading competence (Harris, 1957). Birch and Belmont (1965) in a later study reaffirmed these findings.

Blackman (1966) found that poor readers were more deficient in a right-left directional sense, but his results did not substantiate an association between a right-left directional sense impairment and the number of reading reversals. Mann (1966) studied children trained in dual directionality

by being taught English and Hebrew simultaneously. She found that this dual training had no effect on reversal errors.

The best that the most recent research can do is to confirm the earlier findings that young children do make more reversal errors than older children, and that children who make these errors tend to make less than normal progress in early reading (Teegarden, 1932; Feldman, 1961; Gibson, Gibson, Pick and Osser, 1962; Super, 1969; Rystrom, 1969). The concentration in all these studies is on the subject rather than on the nature of the stimuli.

Exogenic Studies: Most of the studies in the endogenic category ignored the nature of the stimulus. They simply accepted the b d p q as unmodifiable, so they concentrated on pinpointing human variables as the ones most worth studying. The exogenic studies reverse the priorities; they accepted the properties of the subject and concentrated on the nature of the stimulus. So, for example, applying endogenic research to practical application, an educator concerned with reducing b d p q reversals might use a Frostig training program to influence the subject's "perceptual abilities" while an exogenically oriented educator might control the nature of the stimulus. The research reported in this paper derived from the latter orientation and found the following research particularly relevent.

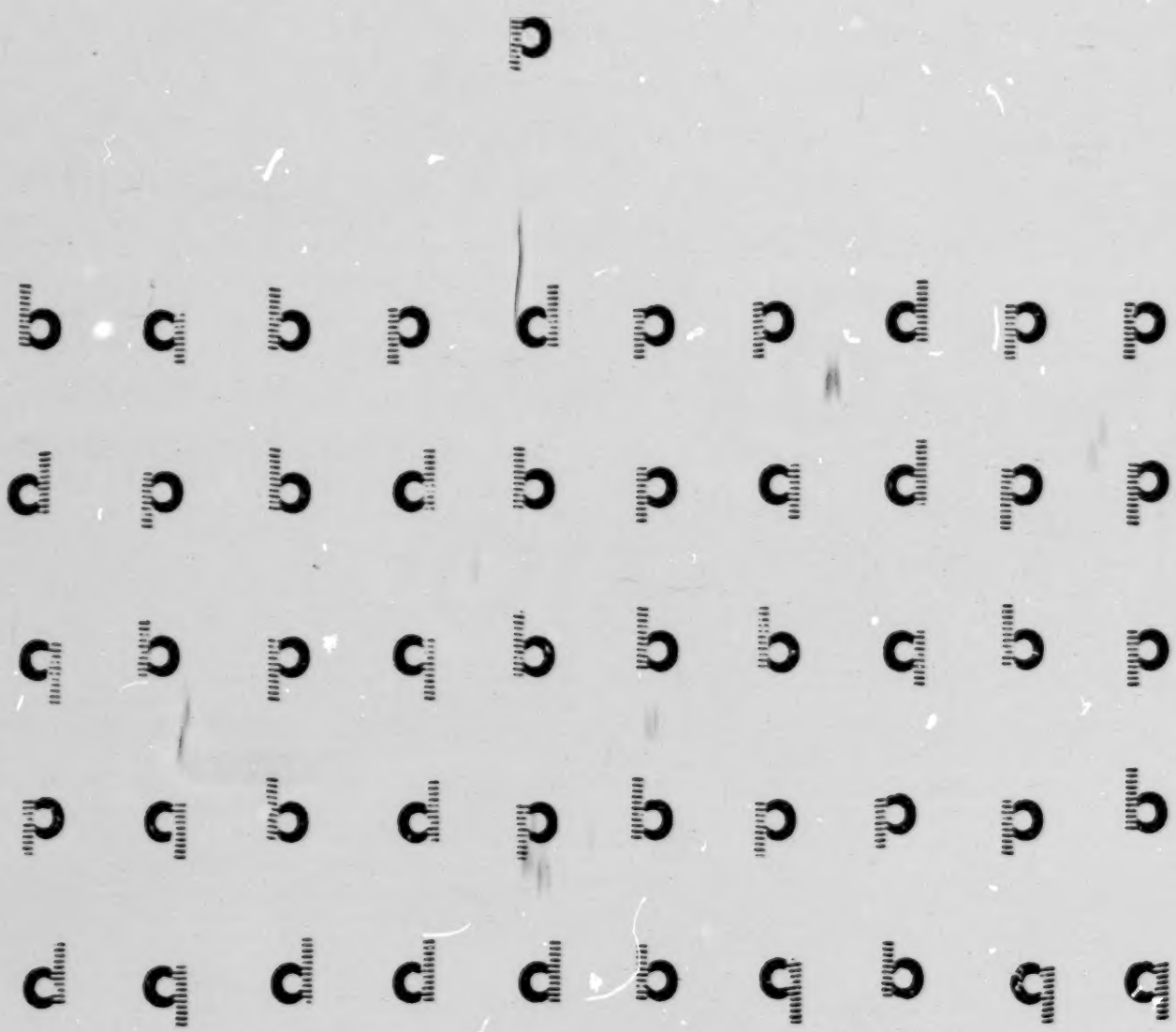
To make children focus on the subtle differences between b and d Hendrickson (1962) used color cues and reduced reversal errors in "immature" children. As early as the 19th century, Sanford (1888) reported his analysis as important stimulus features. Goldscheider and Muller (1893) labelled these ascenders and descenders as the "determining letters." Along with Zeigler (1900), they concluded that these letters dominated or controlled the subject's word perception. Davidson (1935) spoke of the up and down orientation of the contrasting letters q and d. Rotations of b and d were found to occur when the vertical axiel of these letters changed (Wechsler and Pignatelli, 1937).

Fabian's study (1945) discovered that normal young children's rotation errors tended to change horizontal stimuli to vertical. When horizontal features of the stimulus were accented, rotation to vertical increased. Ghent (1960) reported that three and four year olders depend on the upright orientation for recognition of familiar figures. In support of both Ghent and Fabian, Cronin (1966) found that when the triangle's horizontal base is presented on the top rather than on the bottom, response errors increased in young children. Pappalardo (1966) also reported the five year old's clear dependence on the upright orientation for recognition of geometric forms. Three years later, Hulsebus (1969) reported more data to support the young child's attraction to the vertical dimension over the horizontal in support of similar research by Lumsden & Poteat (1968). In most recent years, Nodine and Hart (1970) demonstrated significantly faster word recognition by kindergarteners when stimuli were presented vertically rather than horizontally. Even in the Swedish alphabet, Kuennages and Janson (1969) report vertical linearity to be one of the highest factors of letter loading in lower case letters.

Despite these recent studies, the present emphasis in letter discrimination research among educational psychologists is on endogenic, developmental factors. In fact, almost all these exogenic studies related their findings on stimulus properties to age specific factors. Since the 1960's, Gibson's work (1966) has tried to emphasize studies of the stimulus (Gibson, Gibson, Pick & Osser, 1962; Pick, 1963; Williams, 1969). But this flurry of interest on exogenic factors is consistently dwarfed by the predominance of child development or perceptual models in the endogenic mode. For example, Netzer (1969) preferred to interpret her findings in terms of a perceptual model in the endogenic tradition, playing down the unique feature of her design which was the use of a particular visual stimulus that discriminated poor from adequate readers with a higher correlation than any previous

FIGURE 1

SUBJECT RESPONSE SHEET FOR TASK THREE



research had reported.

The results of these exogenic studies--in particular, the emergence of verticality as the dominating feature of the visual stimulus--led to the major finding in this study.

HYPOTHESES AND RESEARCH DESIGN

If a discriminating feature of the stimulus explains a tendency to reverse letters, and if a clue to that discriminating feature is the young child's tendency toward the vertical, then the common b d p q reversals can be explained (controlled) by the potency of the vertical elements of these letters in the young subject's perceptual field.

Experimental Treatments: To test this major hypothesis, four tasks were administered to four groups of kindergarten children:

All tasks presented letters of uniform size, shape, density and presentation except for certain variations relevant to each of the four experimental treatments. All four treatments required S to match lower case letters to one lower case stimulus letter printed in the center of the page two inches from the top. S's were instructed to draw a cross (X) on each letter on the rest of the page that was exactly the same as the stimulus letter at the top. The letters presented on the rest of the page were designated "response" letters. Task instructions were presented to eliminate "following directions" as a confounding variable.

Each page offered five equal "response" lines of 10 letters each. Response letters included those identical to the stimulus letter and three foils. The occurrence of the stimulus and foil letters in the ten lines was determined by a table of random numbers. All letters were evenly spaced on each line. All letters were 36 pt. Futura Demi type face and of equal density, except on two treatments in which density was an experimental variable.

Task 1: Stimulus figure p. Response figures d b p q

Task 2: Stimulus figure c. Response figures c ⊃ ∪ ∩

Task 3: Stimulus figure p. Response figures d b p q. All vertical aspects of the stimulus and response letters were Bendayed (faded) out.

Task 4: Stimulus figure p. Response figures b d p q. All directional aspects ("humps") of the stimulus and response letters were Bendayed out. Figure One reproduces the actual 8 1/2 x 11 sheet used for Task 3. Except for the Benday of the vertical and directional aspects, all other task sheets were similar.

Specific Hypotheses Tested: If the vertical aspect of the stimulus dominate young children's perception, so that directional features are missed, then the following hypotheses were posed:

H1: $\bar{x}_1 > \bar{x}_4$

H2: $\bar{x}_1 > \bar{x}_3$

H3: $\bar{x}_4 > \bar{x}_3$

in which $\bar{x}$ subscript represent "the mean of Task 1 or 2 or 3 or 4."

The rationale is that Task 2 (directional variations of the letter c) does not have the vertical aspect to divert the child's attention and will, therefore, elicit less errors than Task 1 in which the vertical components of b d p q appear normally. In turn, Task 1 will elicit more errors than Task 3 in which the vertical components are Bendayed out leaving the much darker directional aspect to stand out. In turn, Task 4 in which the vertical aspects of b d p q are emphasized by Bendaying out the directional "humps" will elicit far more errors than Task 3.

Population: A random selection of 180 children were taken from kindergarteners enrolled in a racially mixed urban-suburban school in the greater New York City area. From this population four groups were randomly selected, one for each of the four Tasks. This randomization equated the groups on IQ, SES, sex, race, developmental age, exposure to reading and reading readiness. The mean age of the children was 71.06 months.

Data Analysis: Traditionally, educational research has concerned itself with procedures oriented around rejecting or failing to reject the null hypothesis. That is, the probability of mistakenly rejecting the null (alpha error) is carefully controlled. All too often, however, little attention is paid to the other type of error (beta), i.e., the probability of accepting as tenable a false null (Brewer, 1972).

To minimize the Type II error, while risking a Type I error of one in 20, this design selected an n of 45 and hypothesized, not simply a difference between means, but a difference of at least 50% of the common (within population) standard deviation of the measures of the dependent variable of the comparison groups (J. Cohen, 1969). Thus, with an n of 45, an alpha of .05 on a two-tailed test, an obtained effect size (dc) of .50 or greater was predetermined as the minimal statistical parameters to meet the alpha requirement. These parameters generated a power of .66. An effect size greater then .50 would not only meet the alpha requirement, but would reduce the chance of a Type II error (i.e. increase power).

Most importantly, such an effect size would have educationally practical significance as well as statistical significance.

To test the three hypotheses, each subject's total number of errors was tallied and mean error scores for each group were computed. Simple one way ANOVs tested the observed differences and effect sizes were computed.

A 12 x 12 correlation matrix yielded additional findings on the relationships among the four tasks and such variables as error scores per task, total errors, sex, ethnicity, school and age. J. Cohen's tables (J. Cohen, 1969, p. 87) were used to test for significance of correlations. To test for differences among correlations, Fisher's z transformation function for Pearson's r and Cohen's tables were used. (J. Cohen, 1969, p. 115).

MAJOR FINDINGS AND INTERPRETATIONS

Table 1 shows the results on the test of the dependent variable--number (mean number) of errors committed under each of the four experimental treatments. Table 2 shows the comparison of these results to test the three hyptheses of the study.

Table 1

DISPLAY OF ERROR SCORES FOR EACH OF 4 TASKS

Task	Total Error	$\bar{X}$ Error	S.D.
1	382	8.488	10.882
2	106	2.355	5.015
3	145	3.222	5.057
4	299	6.644	7.068

Table 2

COMPARISON OF TASK EFFECTS TO TEST HYPOTHESES 1, 2, 3

Test of Hypothesis	X Error Scores of Task	Observed Difference ds	F	Alpha
1	1 with 2	.716	11.527	.001
2	1 with 3	.613	8.474	.005
3	4 with 3	.551	6.820	.025

Tables 1 & 2 show that the observed difference in error scores between Task 1 (Stimulus p/Response b d p q) and Task 2 (Stimulus c/Response c) was almost 72% of the common (combined or within) S.D. in the direction hypothesized. The findings exceeded the statistical criteria, supporting hypothesis one. Hypothesis Two was also accepted with the difference in error score between Task 1 and 3 (Stimulus p Response b d p q with vertical Bendayed out) exceeding 61% of the common standard deviation. These tables also show that Hypothesis 3 was supported with a difference of 55% of the common S.D. in favor of the Task 4 condition (Stimulus p/Response d b p q with "hump" Bendayed out). In all three comparisons the verticality aspect of the stimulus figure markedly interfered with childrens' performances. Stated positively, by reducing the dominance of the vertical aspects of the letters, error rate was reduced. The degree of reduction was not only statistically significant, but educationally significant; in every case ds values exceeded the statistical criterion of one-half the common S.D.

The findings are most dramatically seen in Table 3 which shows the number and percent of errors for each type of error. In Task 1, p was the correct response. The subjects could have made a total of 450 errors consisting of a q response for p. They actually made 129 such errors; i.e., 29% of the responses were of this type error. About 15% or 93 responses substituted b for p and so on.

In relation to the vertical dominance theory the findings are dramatically supportive. The least reversal errors in each category are on the stimulus figure that has no vertical aspect (Task 2). The Bendaying out of the vertical aspect (Task 3) reduces errors 50% to 75% over printing the letters without controlling the distracting vertical aspect (Task 1).

Table 3

NUMBER AND PERCENT OF ERRORS FOR FOUR TYPES OF REVERSAL ERRORS

(N = 45)

		TYPE AND TOTAL POSSIBLE ERRORS				
TASK IN RANK ORDER	STIMULUS LETTER	q/p 450	b/d 630	d/q 450	Omit 720	Total 2250
1	p	129 / 29%	93 / 15%	59 / 59%	101 / 14%	382 / 17%
4	p	170 / 38%	42 / 7%	20 / 4%	67 / 9%	299 / 13%
3	p	61 / 14%	35 / 6%	12 / 3%	37 / 5%	145 / 6%
2	p	25 / 6%	17 / 3%	11 / 3%	53 / 7%	106 / 5%

Thus, without denying the developmental factors of visual perception, but holding those constant, simply controlling the features of the stimulus is enough to make a dramatic difference in kindergartners' tendency to confuse b d p q.

OTHER FINDINGS AND INTERPRETATIONS

Table 4 shows how each of the four types of errors correlated with total error. While d to p type error had the lowest error frequency, Table 4 shows it with the highest correlation with total error. In fact, Fisher's transformation analysis indicated that correlations involving d errors were consistently significantly different from all other correlations within each task, which was not the case in comparing correlation differences among correlations of any other error types with a task. This tells us the discriminating p and d involves at least two cues: Cue #1 - the vertical position in space, and Cue #2 - the left to right directionality of the hump. Most children focus on the vertical aspect Cue #1 and trip up on Cue #2.

But the high correlation shown in Table 4 for the p to d error tells us that subjects who are really "in trouble" not only miss Cue #2, but the easier Cue #1 as well. This type of error might prove to be an excellent predictor of reading dysfunction at an early age.

Table 4

CORRELATION OF KIND OF ERROR WITH TOTAL ERRORS FOR EACH OF THE FOUR TASKS

(N = 45)

		TYPE OF ERROR TO TOTAL ERROR			
TASK NUMBER	STIMULUS LETTER	q/ɔ	b/ɯ	d/ɲ	omit
1	p	.7064*	.8174*	.9176*	.7829*
2	c	.3192**	.8856*	.7057*	.9000*
3	ᑭ	.6622*	.5801*	.7958*	.6583*
4	ᑭ	.6325*	.3924*	.7777*	.6310*

* a = .01

** a = .05

Tables 5 & 6 provide us with rather surprizing data about secondary variables that effect this kind of visual discrimination behavior. For example, sex was <u>not</u> a factor in task performance. The traditional view that girls do better than boys on school related tasks was not borne out in this data. The same thing occurs for ethnicity and SES variables. Unlike most school-related research, this study finds <u>no difference</u> in the performance and type of error between middle class and lower class children and between black and white children.

These findings are consistent with other findings (Cohen, 1970; Mueser, 1971) that low SES blacks learn what they are taught; that is, deficits in school related behaviors represent pedagogical deficiencies, not innate or aptitude deficiencies. The schools from which the experimental population was drawn teach letter discrimination thoroughly in kindergarten and low SES children learn it. High SES children may already know it before they are taught. Thus, the high error pupils in this study represent a "truly" deficient group in letter matching independent of their SES or ethnicity.

Table 5

CORRELATION OF TOTAL ERRORS ON EACH TASK WITH SEX, RACE, AGE AND SCHOOL

(N = 45)

	TASK 1 p	TASK 2 c	TASK 3 >	TASK 4
SEX	- .15	.01	- .13	.03
RACE	- .28	.16	- .14	.09
AGE	.07	- .46 *	- .09	.04
SCHOOL	- .12	- .05	.04	- .24

Note: Negative correlation on Sex refers to female gender.

Negative correlation on Race refers to white race.

Table 6

CORRELATION AMONG VARIABLES OF RACE, SEX, AGE AND SCHOOL ON FOUR TASKS

	TASK 1 p	TASK 2 c	TASK 3	TASK 4
RACE TO SCHOOL	- .82*	- .73*	- .70*	- .71*
RACE TO AGE	.30**	.16	.00	. 15
SEX TO RACE	- .14	- .02	- .30**	. 02
SEX TO AGE	- .10	.11	.29**	. 03

* significant at alpha .01

** significant at alpha .05

Negative correlation on sex refers to the female gender.
Negative correlation on race refers to the white race.
Negative correlation on school refers to low S.E.S.

In this school system the heavy teaching of letter discrimination has put the "disadvantaged" student on a par with the advantaged. About 50% of the subjects had two or less errors. About 30% were exceeding 80% accuracy. Left over is the "truly" dysfunctioning group. This kind of dysfunction seems to be independent of SES.

CONCLUSION

The vertical properties of b d p q influence letter reversal behavior of kindergarteners. Reduce the dominance of the vertical aspects of these letters, and reversal errors are markedly reduced. This modification of the stimulus overrides the effects of child development. Evidently an attraction to the vertical to a degree of distractibility seems to have an interaction effect with left or right directionality.

Two error-causing constructs seem to explain b d p q reversals: "high distractibility to the vertical" and "poor sense of directionality." The former, not the latter, carries more weight in producing these reversals. From a practical point of view, it appears wiser to invest money and effort in controlling the effect of the vertical aspect than in training children in directionality.

This study supports the point of view that the nature of the learning task rather than the psychosocial factors beyond the classroom domain should take first priority in designing curriculum. If the realities of child development demonstrate that b d p q discriminations are, in general, beyond the young child's repertoire, and if we choose to teach these children to read, then the logical path is to adjust the learning strategies to fit the child by controlling the nature of the stimulus. In this case, changing the goal or restructuring the child becomes unnecessary.

At a much deeper level, this study demonstrates a specific approach to educational research that concentrates on the nature of the stimulus, reponse or contingency rather than on the nature of the subject. The study evolves from a point of

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view that defines educational research as a domain related to, but distinct from, research in behavioral and social sciences. Educational research defines its domain as human behavior rather than child development. The latter leads to manipulation of such constructs as directionality and laterality. The former concentrates on manifest features of stimuli, response and feedback conditions. The educational researcher's domain concentrates on isolating those malleable factors that strengthen prediction and control of human behavior, for these are the issues that face the professional educator.

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